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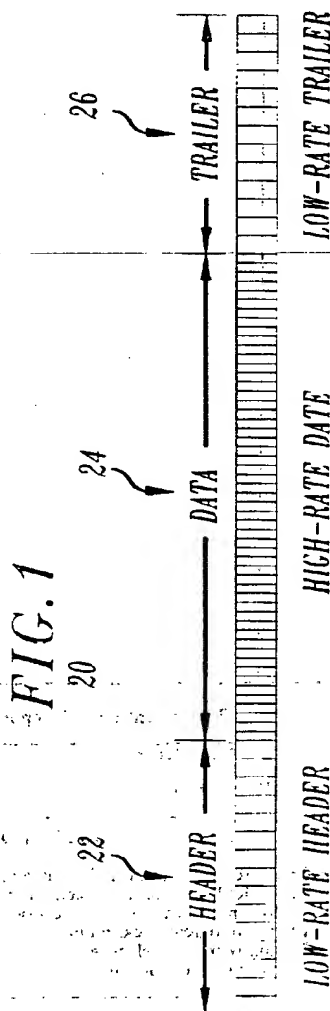(71) Applicant : AMERICAN TELEPHONE AND
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(54) Optical packet field coding.

(57) Currently, with optical time division multi-plexing, a switching node is operated at the peak transmission rate. For example, if the data transmission rate is 10 Gbps, the line cards in the switching circuit are also required to operate at this rate despite the fact that the switching node does not actually need to access the data at this rate. Thus, the electronics, which includes the line cards at the switching node is expensive and less reliable than a low-speed design. In this invention, the requirement of operating the switching node electronics is eliminated by encoding the packet header field (22) at a lower rate than the information in the data field (24). As a result, the line cards need only operate at the lower header rate. This is possible because the switching node does not need to process the data portion of the packet, but only the header information. The high-speed data portion (24) of the packet is not optically to electrically converted at the switching node, but it passes almost transparently through the switching node. The invention also discloses overlapping several logical networks on the same physical network.

FIG. 1

EP 0 491 495 A1

Technical Field

This invention relates generally to optical networks and more particularly to the method and apparatus of bit encoding of an optical packet.

Background of the Invention

The advent of gigabit-per-second packet networks has focussed the attention of optical network system designers on the need to provide selected users with gigabit-per-second network access together with a high-speed multiplexing system which can be used to access an optical channel. One approach frequently suggested is the use of lower speed channels with wavelength division multiplexing. Unfortunately, since this approach requires dividing or "chopping" the high speed traffic into multiple streams for transmission on several channels, relatively complex traffic synchronization and/or reassembly procedures are required at the receiving end. It is noted that statistical time division multiplexing does not suffer from this disadvantage. It does, however, require electronic switching of multiplexed traffic at the peak channel rate. Switching at this high rate is both complex and expensive because this is the rate at which a line card of a switching node must operate. For example, if the transmission rate of the data is 1 Gbps, the line card must detect and process the packets at 1 Gbps. Very high speed electronics is expensive and the technology is, as yet, not sufficiently mature. Thus, there is a need to avoid the limitations of high speed electronics.

Summary of the Invention

Currently, with optical time division multiplexing, the switching node is operated at the peak transmission rate. For example, if the data transmission rate is 10 Gbps, the line cards in the switching circuit are also required to operate at this rate despite the fact that the switching node does not actually need to access the data at this rate. Thus, the electronics, which includes the line cards at the switching node, is expensive and less reliable than a low speed design. In this invention, the requirement of operating the switching node electronics at the high speed link bit rate is eliminated by encoding the packet header field at a lower rate than the information in the data field. As a result, the line cards need only operate at the lower header rate. This is possible because the switching node does not need to process the data portion of the packet, but only the header information. The high-speed data portion of the packet is not optically to electrically converted at the switching node, but passes almost transparently through the switching node.

Brief Description of the Drawing

Fig. 1 is an illustration of a packet in accordance with the principles of the invention;

Fig. 2 is an illustration of a switching structure in accordance with the principles of the invention for switching and processing the packet of Fig. 1;

Fig. 3 is an illustration of a network in accordance with the principles of the invention wherein several logical networks are overlayed as a single optical physical network;

Fig. 4 is an illustration of an existing architecture of a switching node of a multi-hop network;

Fig. 5 is an illustration of the architecture of Fig. 4 with low-speed line cards being substituted for the high-speed line cards;

Fig. 6 is an illustration of an 8x8 Shufflenet;

Fig. 7 is an illustration of a switching node for use in a Shufflenet network having a header rate of 100 Mbps and a data rate of 1 Gbps;

Fig. 8 is an illustration of a Blazenet network

Fig. 9 is an illustration of a switching node in accordance with the principle of the invention for use in the network of Fig. 8; and

Fig. 10 is an illustration of a network for multi-medium traffic integration in accordance with the principles of the invention.

Detailed Description

Optical transmission systems can be classified as being "all optical network" or "almost all optical networks." In these networks, messages and/or packets are converted to an optical signal upon their entry into the network, where they are then forwarded and switched as optical signals within the network. At the destination, they are converted back into an electrical signal. The difference between "all" and "almost all" optical networks is that in "almost all" optical networks the data path is optical, but the switching control is electronic. In contrast, in "all" optical networks, the complete network, the links, switching nodes and network interfaces are fully optical. Thus, in the "all" optical network the logic elements and memory are optical. An example of an "almost all" optical network is disclosed in the "IEEE Transactions on Communications", June, 1990; "Blazenet" by Z. Haas et al. An approach to an "all" optical network is disclosed in the "IEEE Journal on Selected Areas in Communications", December 1986, "Ultrafast All-Optical Synchronous Multiple Access Fiber Networks" by P.R. Prucnal et al.

A primary reason for using an "almost all" optical network having an optical transport in combination with electronic control pressing is to preserve the investment which has been made in hardware and in media deployment as the network bit rate increases. Advances in optical hardware products may make the

electronic switching nodes of today's networks obsolete. As noted in "OFC 1990 Postconference Edition, San Francisco, CA, Jan. 22-25, 1990, "20 Gbit/s 100 km Non-Linear Transmission With Semiconductor Source" by I.W. Marshall et al.; the bandwidth distance of 2000Gbps.km is achievable today.

The main objection to optical high-speed time division multiplexing is the requirement that the switching node must operate at the peak transmission rate. If, for example, the data transmission rate is 10 Gbps, than the line cards in the switching node are also required to operate at this rate, despite the fact that the switching node does not actually need to access the data at this rate. Electronics operating at 10 Gbps are relatively expensive and, in addition, the technology is not fully developed. In this invention, we solve this problem by separating the switching operation from the transmission operation. Such separation provides the additional advantage of permitting independent changes in the switching of the optical signals or in the transmission facilities. Thus, for example, increasing the data rate to 100 Gbps requires virtually no change in the switching nodes.

In this invention, the separation is obtained by using different bit rates for the header field, the trailer field, and the data field of the optical packet. Hence the name field coding. Referring to Fig. 1, there is illustrated a packet in accordance with the principles of the invention. In Fig. 1, the packet 20 can comprise a header section 22, followed by a data section 24, which may be followed by a trailer section 26. When the packet is formed, the header section 22 and the trailer section 26 are encoded with information at a rate which is compatible with the operating speed of the electronic switching or processing equipment. The data section 24, however, is encoded with information at a rate which is compatible with the speed of transmission links. Since the switching node does not need to process the data section of the packet, the switching node can operate at the lower header rate, and the fast rate data field can pass almost transparently through the switch. Thus, as the data portion of the packet is not converted by the switch from its optical form to an electrical signal, the structure for switching the optical signal is that of an almost all optical network.

Referring to Fig. 2, there is illustrated a structure in accordance with the principles of the invention for operating a switch at a speed commensurate with the level of pressing required to support a very much higher speed network operation. A signal comprising a packet of the type disclosed in Fig. 1, which has a low rate header section and a high rate data section, is transmitted from a station along an optical fiber link 30 to an optical coupler 32. The optical coupler 32 diverts a small portion of the optical signal in the optical link 30 to a low speed receiver 34, and the major portion of the optical signal is passed by the coupler

through a delay 36 to a photonic switch 40. The low speed receiver detects and reads the header information of the packet received at the lower header rate. The low speed electronic signal from the low speed receiver is directed to a low speed electronic control 38, which is coupled to control the operation of a photonic switch 40 to direct the optical signal from the delay 36 to a desired optical link 42, 44 or 46, for transmission to the header designated destination. Other operations based on processing of the low-speed header may be performed.

Thus, the control 38 sets the transmission path through the photonic switch. The packet is temporarily delayed in the delay line 36 to compensate for the electrical control processing time and for the time required to activate the photonic switch 40. It is to be noted that the high rate data signal is not pressed at any time during the switching operation. Thus, it can be stated that the switching press is transparent to the high rate data information. Optical amplification of the optical signal may be required, depending on the network parameters.

The need for very fast electronic memories for electronic switches is one of the parameters that determines how fast a switching node can operate. In optical implementation, the optical memory can be a problem. Large and fast optical random access memories are difficult to implement. Some architectures such as, for example, Blazenet, cope with this limitation of photonics by employing an alternative network architecture that effectively reduces or today eliminates the need for local buffering within the switching nodes. In Blazenet, for example, it is done by utilizing the inherent storage of the optical media to provide buffering. Contention resolution can be performed in "almost all" optical networks by

- Blazenet/Blazelan line architecture,
- Hot potato routing,
- Local optical delay-line buffering, and/or other approaches.

It is possible to implement the idea of field coding by Time Division Multiplexing (TDM), Wavelength Division Multiplexing (WDM) or Space Division Multiplexing (SDM). Thus, the low-speed control channel can be realized as time-multiplexed on the same channel (TDM), on a different wavelength (WDM), or even as a totally different fiber (SDM). An advantage of the TDM system is that it readily provide framing information. However, some of the data channel capacity is wasted due to the low rate header. In WDM and SDM this wasted capacity can be confined to a separate channel to increase the available data capacity. However, WDM and SDM may be more expensive to implement and impractical in long span network because of the synchronization problem.

Referring to Fig. 3, there are illustrated several logical networks overlaid on a single physical network using the principles of this invention. For example,

assume an environment where there is a need for an interconnect network to support three separate networks such as 10 Mbps (Ethernets) 50, 100 Mbps Fiber Data Distribution Interface (FDDIs) 52, and 1 Gbps (high speed LANs) 54 coupled to form a ring. It is, of course, possible to build three separate physical networks. However, another approach is to integrate all the three networks on the same physical networks, by using the field-coding technique. Such an arrangement is shown in Figure 3. The header structure on the ring contains a simple two-bit indication to identify network a packet belongs to. Every node has the capability to read the low-speed header and determine whether the packet belongs to its network. If so, the packet may be extracted from the ring, by the receiver that is compatible with the data rate of the packet. If not, the data-field is not read. Thus, for example, only 10 Mbps capability is required in the nodes that belong to the 10 Mbps network. The major advantage of such an arrangement is that it reduces the amount of required fiber, i.e., a single physical media is shared by several different and distinct networks. Moreover, upgrading a network nodes requires changes only in the node design, not in the fiber routing. Thus, for instance, there is no need for any fiber rerouting for a customer that is connected to the 10 Mbps network and needs a new connection to the 100 Mbps network.

Encoding the header and the data at different signaling rates, as disclosed here, is particularly attractive in multi-hop networks. In multi-hop networks, the switching nodes must examine a packet upon its arrival to determine on which output port the packet is to be sent. If the header is low-rate encoded, the line card circuits that are responsible for examining the packet header can be significantly simplified. This is illustrated in Figs. 4 and 5.

Fig. 4 illustrates the architecture in use today. Fig. 5 illustrates the architecture which can be substituted for the currently used architecture when using the principles of the invention. In Fig. 4 each of the vinous high speed line cards 60, 62, 64, 66, 68 and 70 can be removed and replaced with low speed line cards 72, 74, 76, 78, 80 and 82 as shown in Fig. 5.

Of course, the local traffic still needs to be modulated/received by a high speed transmitter/receiver. However, this requires only a single high-speed transmitter/receiver per switching node. Thus, the saving is very dramatic in a network with nodes that have a large number of incoming/outgoing links.

In a hot-potato network, a packet that cannot be forwarded on the required link because the link is used by another packet, is sent on another thee link, possibly even in the wrong direction. Hot-potato networks do not require switching memory and, therefore, are suitable for "almost-all" optical implementation. The issue of resolution of contention is non-existent in a hot-potato routed network because blocked packets need not be stored. A possible hot-potato architecture is Shufflenet network as illustrated in Fig. 6. See "AT&T Technical Journal" Nov/Dec '87, "Terabit Lightwave Networks; The Multihop Approach" pages 21-34.

A Shufflenet switching node design, when using field coding in accordance with the principles of this invention with a low rate header and high speed data, is illustrated in Fig. 7. It is to be noted that the two line cards 90, 92 are designed to operate at the lower rate. Only the local traffic transmitter 94 and receiver 96 need to have high speed capability.

Blazelan is an "almost-all" optical network. See U.S. Patent #4,970,717. It uses the fiber link storage as contention buffering scheme; i.e., blocked packets are recirculated in the optical links. Blazelan is a particularly attractive scheme to be used in conjunction with the field-coding technique, since the contention is resolved without the need to locally buffer the data. The network is targeted towards very high-speed communication with the simple source-routing algorithm. Moreover, it is a multi-hop network, and, therefore most of the traffic handled by an "average" switching node is through traffic rather than local traffic, and data field of through traffic need not to be detected. In fact, the connectors that are used to increase the distance between switching nodes have no local traffic, and therefore can be built inexpensively. Moreover, since the loop-replication technique that is used to reduce the effect of input queueing on the Blazelan switch performance increases the number of line-cards, the field-coding technique may considerable reduce the cost of the implementation of the loop-replication technique. An example of a Blazelan network is illustrated in Fig. 8 and an illustration of a switching node for use in the network of Fig. 8 which operates with a field coded packet, as here disclosed, is illustrated in Fig. 9.

High-speed user access is an important challenge the research community is struggling to solve. As local-area networks are increasing in speed, there is a need for high-speed interconnection, so that the high-speed user access will not be slowed down by the interconnection bottleneck. An approach would be to use a Metropolitan Area Network (MAN). Unfortunately, MANs are designed today to support speeds comparable with LANs. Thus interconnecting LANs with MANs results in the interconnection bottleneck. Consequently, a new type of interconnection is needed that will be able, on one hand, to support user rates comparable to the LAN rates and, on the other hand, provide aggregate throughput well above single user access. Moreover, such a network is required to provide connectivity among different and incompatible LANs. We have presented such an interconnection scheme that is based on the separation of transmission from switching. The ever increasing transmission rates will have virtually no effect on the

design of the switching hardware. Thus the field-coding scheme preserves investment. Moreover, different and distinct networks can be integrated over the same optical subnet. This may be in particular attractive to achieve multi-media traffic integration, especially, since users may require different services. Thus, for example, if a user requires no video, the user connection to the video rate may be missing. Such an arrangement is shown in Figure 10.

Claims

1. The method of encoding an optical packet having a header field portion and a data field portion comprising the steps of
   encoding header information in said header field portion of said packet at a first bit rate, and
   encoding data information in said data field portion of said packet at a second bit rate different than that of said first rate.

2. The method of claim 1
   wherein said second bit rate is higher than said first bit rate.

3. The method of claim 2 wherein said packet has a trailer field portion
   further comprising the step of
   encoding tailer information in said trailer field
   portion at a bit rate substantially equal to that of said first bit rate.

4. The method of claim 1
   further comprising the steps of
   forming a second packet having a header field portion and a data field portion,
   encoding header information in said header field portion of said second packet at a third bit rate which is equal to that of said first bit rate, and
   encoding data information in said data field portion of said second packet at a fourth bit rate which is different from that of said first, second and third bit rates.

5. The method of claim 4 wherein said second packet has a trailer field portion
   further comprising the step of
   encoding trailer information in said trailer field,
   portion of said second packet at a bit rate substantially equal to that of said first bit rate.

6. A switching node for an optical packet having at least a header field portion and a data field portion

where information encoded in said header field portion is encoded at a first rate that is different from a second rate at which information is encoded in said data field portion
   comprising
   receiver means adapted to read and convert from optical to electrical form only the information encoded at said first rate in said packet,
   control means coupled to receive electrical signals from said receiver means,
   optical coupler means coupled to pass a received optical packet both to said receiver means and to an optical delay means, and
   optical switching means having an optical input port and at least two optical output ports for controllably switching an optical packet at said input port to an output port controlled by signals from said control means to switch the packet from said delay means to a selected output port.

7. The switching node of claim 6
   comprising
   delay means interposed between said optical coupler and said optical switching means to prevent the packet from the coupler from reaching the input port of the switching means before said switching means is activated by signals from the control means.
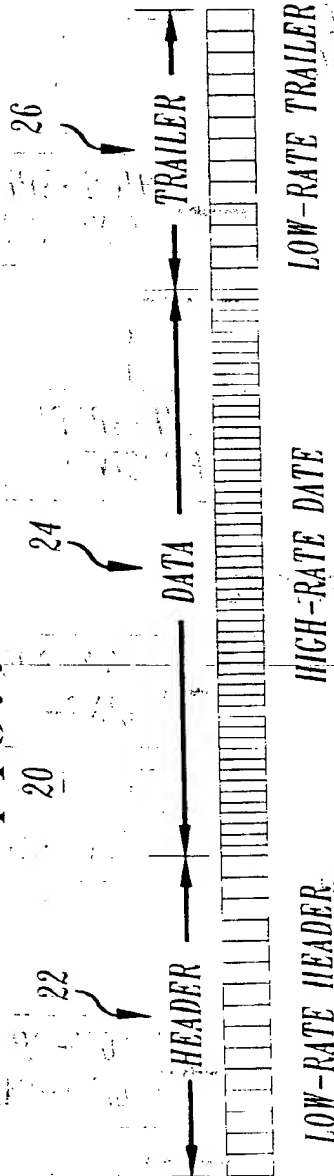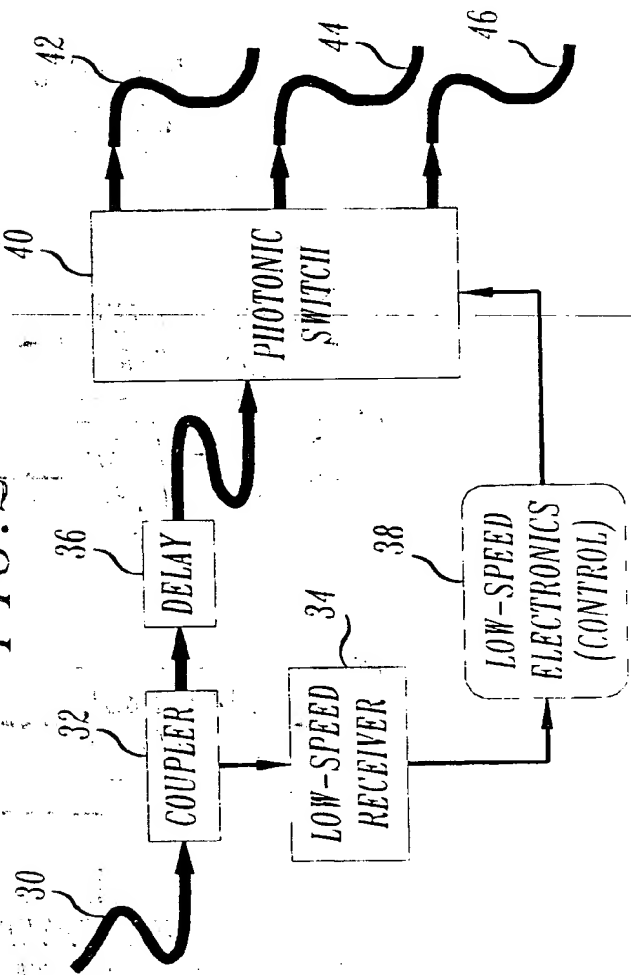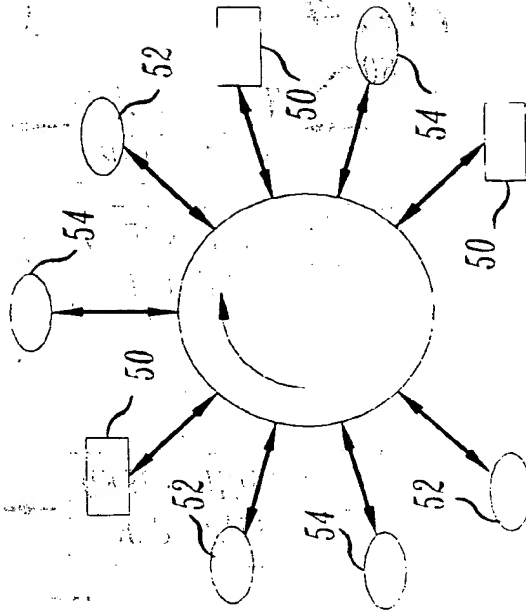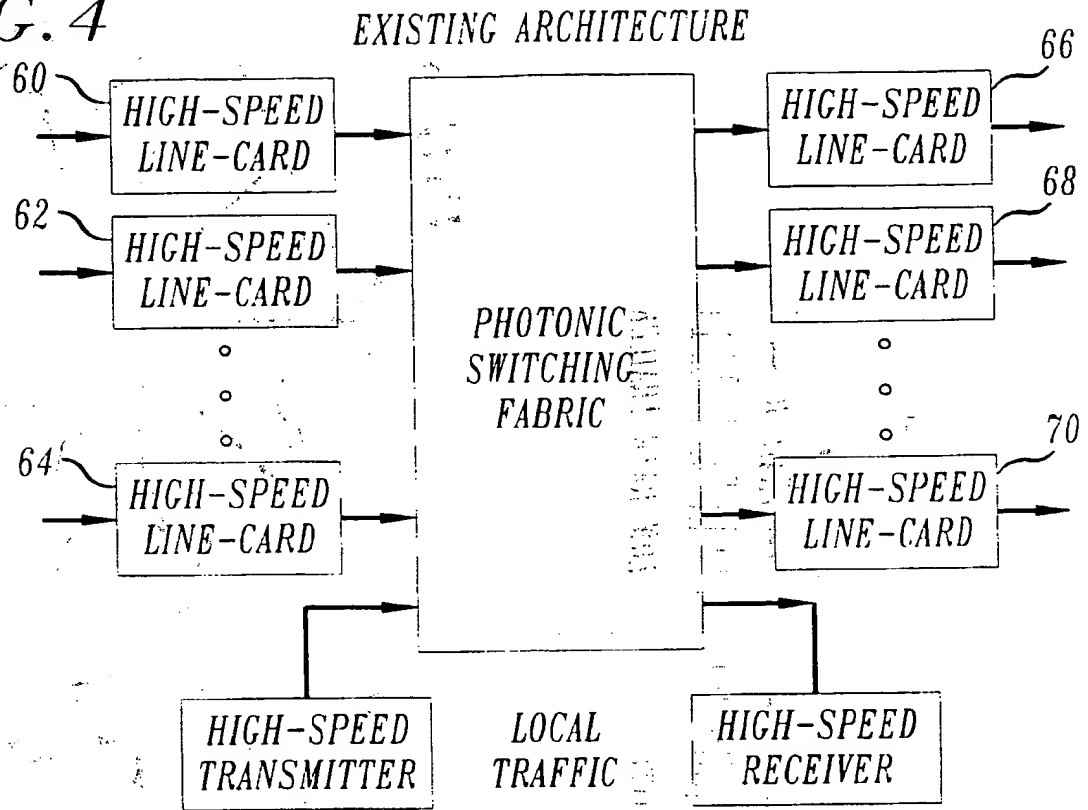
FIG. 3

FIG. 1

FIG. 1

HEADER — 22

DATA — 24

TRAILER — 26

20

LOW-RATE HEADER

HIGH-RATE DATE

LOW-RATE TRAILER

FIG. 2

30

COUPLER — 32

DELAY — 36

PHOTONIC SWITCH — 40

LOW-SPEED RECEIVER — 34

LOW-SPEED ELECTRONICS (CONTROL) — 38

42

44

46

FIG. 3

50

52

54

FIG.4   EXISTING ARCHITECTURE

```
60  HIGH-SPEED                          HIGH-SPEED     66
    LINE-CARD                           LINE-CARD

62  HIGH-SPEED                          HIGH-SPEED     68
    LINE-CARD        PHOTONIC           LINE-CARD
                     SWITCHING
                      FABRIC
64  HIGH-SPEED                          HIGH-SPEED     70
    LINE-CARD                           LINE-CARD


    HIGH-SPEED        LOCAL             HIGH-SPEED
    TRANSMITTER       TRAFFIC           RECEIVER
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FIG.5   NEW ARCHITECTURE

```
72  LOW-SPEED                           LOW-SPEED      78
    LINE-CARD                           LINE-CARD

74  LOW-SPEED                           LOW-SPEED      80
    LINE-CARD        PHOTONIC           LINE-CARD
                     SWITCHING
                      FABRIC
76  LOW-SPEED                           LOW-SPEED      82
    LINE-CARD                           LINE-CARD


    HIGH-SPEED        LOCAL             HIGH-SPEED
    TRANSMITTER       TRAFFIC           RECEIVER
```

FIG.6

FIG.7

FIG.8

FIG.9

INPUT LOOP

DELAY LINE

SWITCH FABRIC

LOW-SPEED LINE-CARD

CONTROL (ELECTRONICS)

TO
OUTPUT LOOP

FIG.10

STATION 2
VIDEO   VOICE

STATION 1
VIDEO
VOICE
DATA

STATION 3
VOICE

VOICE   DATA
STATION 5

DATA
STATION 4
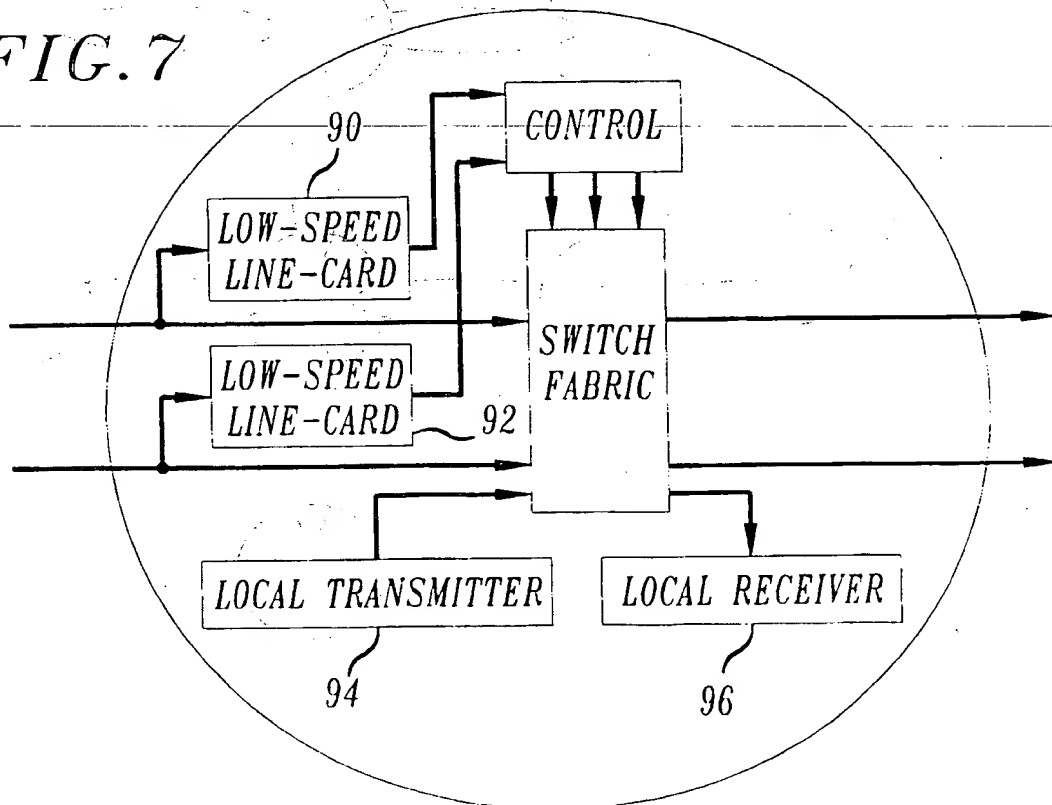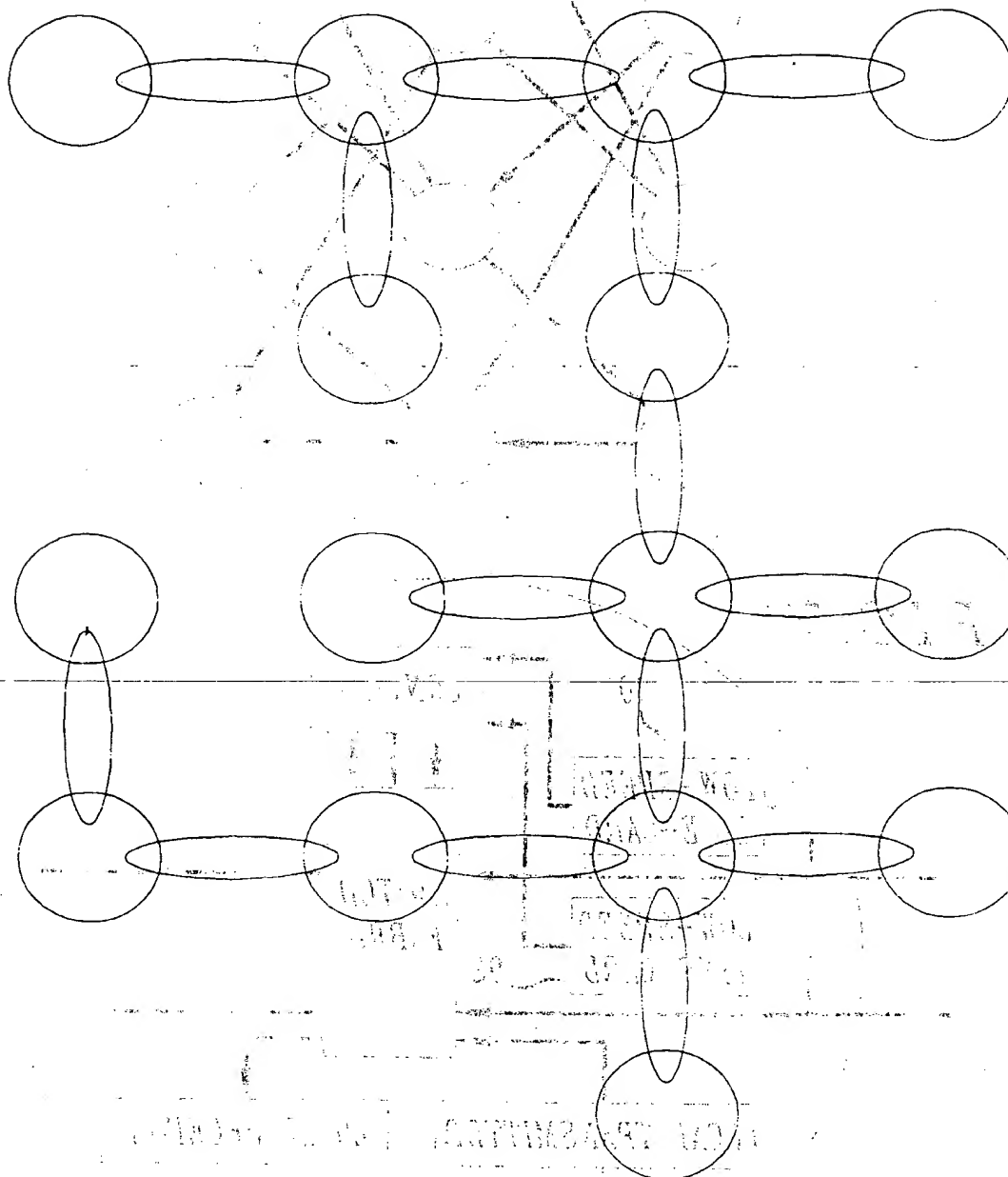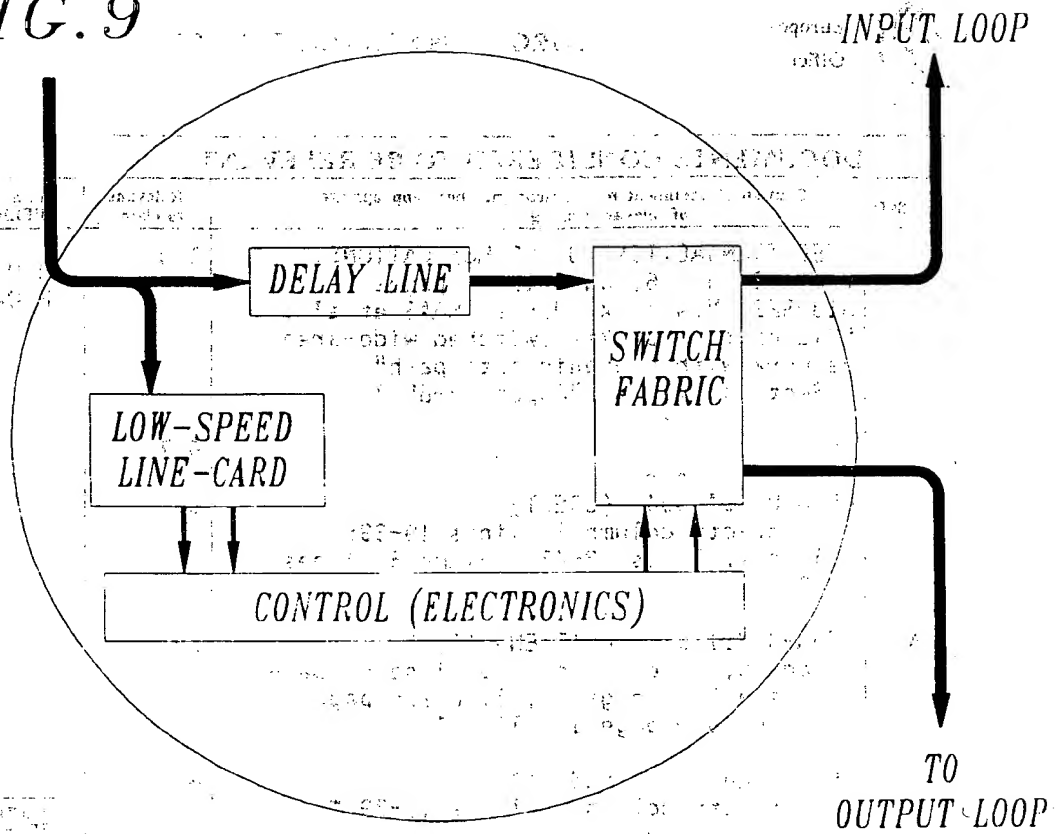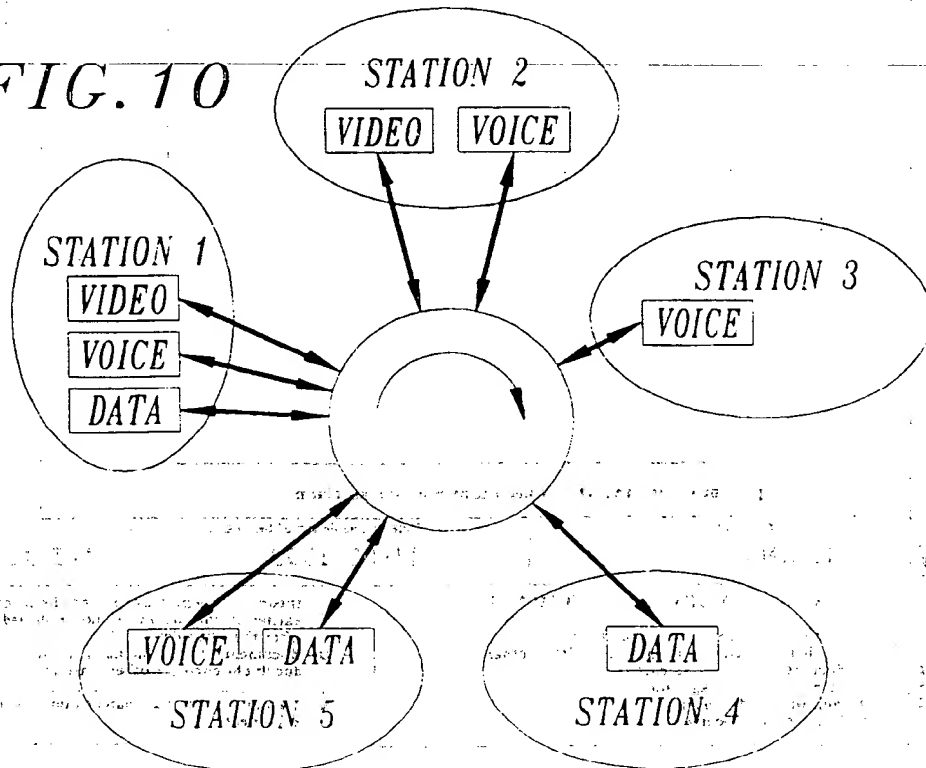
European Patent
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EUROPEAN SEARCH REPORT

Application Number

EP 91 31 1236

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
D,X	IEEE TRANSACTIONS ON COMMUNICATIONS, vol. 38, no. 6, June 1990, pages 818-829, New York, US; Z. HAAS et al.: "Blazenet: A packet-switched wide-area network with photonic data path" * Section III. A: "Appendix-B" *	1-5	H 04 L 12/56 H 04 Q 11/00
Y	IDEM	6,7	
Y	EP-A-0 334 054 (CSELT) * Abstract; column 3, lines 19-39; column 4, lines 32-48; column 6, lines 30-36 *	6,7	
A	DE-A-3 211 966 (SIEMENS AG) * Page 8, line 3 - page 9, line 5; page 11, line 23 - page 12, line 23; page 16, line 9 - page 17, line 18 *	1-3,5	
A	EP-A-0 282 071 (CSELT) * Abstract; column 3, lines 13-39 *	4	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
P,X	WO-A-9 101 603 (BRITISH TELECOM PLC)	1,2,4	H 04 L H 04 Q H 04 J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	11-02-1992	ALI A.

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